Paper Objects Made through Laser Cutting and Scoring: a Smooth Step from Digital Printing to Digital Fabrication

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Abstract

A new process is described, that allows the cutting and scoring of paper with a laser diode. The laser cutting step comes after an inking step, in which the lines to be cut are ink-jetted with an ink that absorbs the laser radiation. This technology patented by CEA appears as an attractive low-cost technology for creating 3d personalized paper objects. Business models associated to that technology are discussed, and licensing opportunities are presented.

Introduction

The fantastic development of Digital Printing during the last decade evidenced the strong need that computers produce tangible outputs, and not just files. This outcome was not so clear 15 years ago, when many claimed, and Xerox advertised, that paper was doomed because of modern Digital displays. Some interesting lessons have been drawn from the obvious failure of the myth of Paperless office [1]. In particular, the importance of printed paper as a tangible media to work or to play with has been evidenced. Handing a printed document to others is both a sign of deference and an opportunity to create direct interaction. Printed photos may be handed out as a gift; while transferring Mbyte files containing the same images may not be recognized as so. The possibility to put paper nearly anywhere, which has been still augmented by the invention of Post It® notes, turns paper into a very efficient active reminder system. It is a very powerful way for people to put their imprint in space, at office or at home. Last, but not least, paper can be easily stored and discarded, so it has negligible possession costs.

However, for a number of objects made of printed paper, it is necessary to use special format media. Greeting cards, photos, decoration labels, name badges, should be printed not only on the proper paper grade, but also in the proper format. This imposes a limitation on paper object printing and creation. Cut-out figurines, as sketched in Figure 1, and other personalized paper crafts, can not be obtained from precut media.

As a consequence, it would be very attractive to have the ability to cut paper within a Digital Printer. The ability to cut sheets of media conjunction with Digital Printing is available in so-called vinyl plotters used for signage. These mechanical blade cutting tools are designed to cut special vinyl media, but not paper. Adaptations have been marketed to cut cardboard, but the necessity for a sacrificial backing material, the limitations in terms of achievable radius of curvatures, and the mechanical stress on the paper, limit their use to dedicated scrapbooking applications. Laser cutting systems do not suffer such limitations. Desktop USB-controlled systems are available based on CO_2 lasers. However, the economies of CO_2 gas laser systems are such that they are beyond the reach of the typical office and home.

Figure 1: *Integrating printing and cutting ability turns photo into self standing paper objects.*

In this paper, we present a low cost solution for cutting paper, using a laser diode, in conjunction with Digital Printing. We present the principle of operation and experimental validation of the technique. We illustrate different possibilities opened by this technique. We also analyze the business models that may be associated with this innovation, in digital fabrication kiosks, in personal printers, and in professional applications.

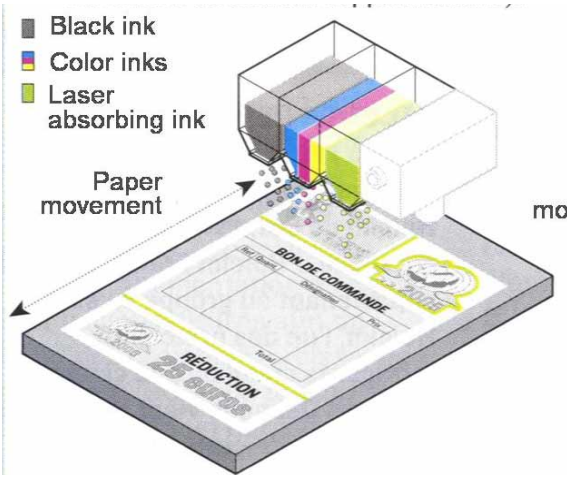
Principle and experimental demonstration

The innovation is based on a single emitter laser diode with a power of approximately 1W. By itself, the laser diode cannot cut paper, as white paper does not absorb the Near Infrared (NIR) light emitted by the laser.

The key of our innovation is to use an additional inkjet cartridge with an NIR absorbing ink, having a lambda max (absorption maximum) consistent with the wavelength of the laser diode, that is able to penetrate deep into the paper. The lines and shapes to be cut are first inked using this NIR absorbing ink. This is done in the printing step, at the same time as the conventional inkjet cartridges print text and graphics on the page. In a second step, the laser is moved along the lines to be cut. The NIR

absorbing ink allows good interaction between paper and the laser, and the paper can therefore be ablated by the laser. The process is sketched on Fig. 2.

1) First step: graphic inks and NIR absorbing ink are jetted on paper



1) Second step: by combining the longitudinal movement of the paper and the lateral movement of the laser head, the beam follows the NIR absorbing lines

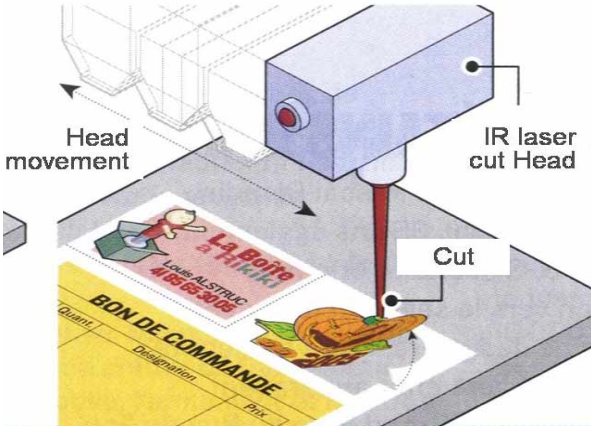


Figure 2: Sketch of our innovative laser-based cutting process

This innovation was patented in January 2003, with international extensions [2]. The novelty and inventiveness of the innovation is supported by the French, the PCT and the US search reports.

This process has been validated experimentally [3]. Different types of inkjet heads are available, each having different abilities to handle fluids. It is widely acknowledged that the so-called "thermal inkjet" technology may handle inking fluids in a narrower range than the "piezo inkjet" technology. We chose to perform our demonstration using the most demanding technology, which is integrated into Hewlett Packard Printers. We used an older generation HP 1200C inkjet printer, which is believed to deliver larger drop volumes than more recent printers. The select NIR dyes were supplied by H. W. Sands Corp. The inks were formulated by diluting the NIR dyes into water + 2-propanol. Similar NIR dyes are commonly used for different security (verification and authentication), imaging and marking applications. An appropriate HP black cartridge was emptied and refilled with the specially formulated NIR ink. Using this ink, lines were printed on a conventional 80g/m^2 paper.

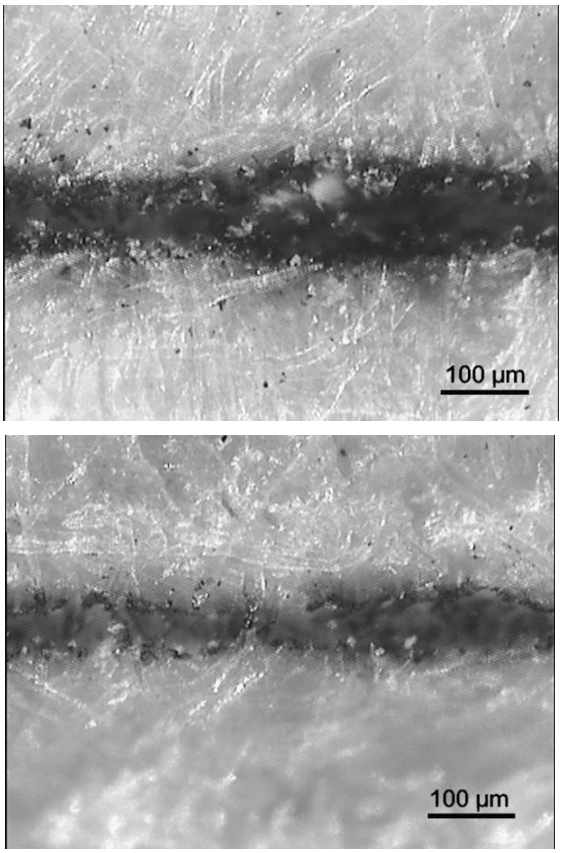


Figure 3: *Laser cuts obtained on paper marked using invisible NIR absorbing ink: a) complete cut; b) half-through partial cut, producing an easy folding line.*

The laser cutting experiments were performed on a separate system, based on a 1 W single emitter laser diode. This type of diode is about 3 times more powerful than the laser diodes used in DVD writers, but has less stringent requirements in terms of optical focusing quality. The laser light was focused on the paper into a 30µm spot using a 2-lens optic. It was checked that when the laser light impinges on the paper, no cutting or even browning of the paper occurs. This is consistent with the very low absorption of the laser light by the paper. When the laser spot impinges on the line inked with the Near Infrared ink, the laser interacts with the paper. Depending on the speed and power of the laser, the paper may be either completely cut, or turned into an easy detachable line, or an easy folding line. More extensive details have been published elsewhere [3, 4]. Typical cutting results are illustrated on Fig. 3.

Digital paper crafts

Our environment is rich in 3-dimensional objects made of paper or light cardboard. The most prevailing class of 3-d paper objects is packaging, which is a field with major business stakes; however, many other 3-D objects including either office goodies or photo-frames are also commonly made of paper. Fabrication of these 3d paper-based objects is presently achieved by industry, but it lacks the ability to customize to individual demand, or to offer the option for personal creativity. In addition, in the absence of a device that is able to adequately perform the cutting and scoring operation, the prevailing business model is "cut then distribute", eliminating the potentially attractive option of distributing the patterns electronically, with subsequent cutting into real media at the end user's desk or retail shop.

Our system represents a very attractive opportunity to allow the creation of 3d objects with personalized features, while a significant part of the conception of the cut and fold arrangement remains computer-assisted, and electronically distributed.

Figure 4: *Examples of 3-d paper objects that may be produced from a terminal with print, cut and score ability.*

A potential limitation of this system is that the 3d object is not produced directly, since it has to be handcrafted by a few folding and gluing operations; however, this may not be a drawback, since many people appreciate the fact that they can manipulate the paper [1]. Indeed, in view of the wide interest in scrapbooking, one may even think that customers may prefer the personal manipulation required to perform the final assembly. The scrapbooking craze further underlines the number of personalized paper-related objects that may be wanted in a home. Our system is very attractive in view of this.

Business model

The laser print and cut system can be integrated in a printer, a vinyl cutter, or a photo kiosk. With proper software it may transform a printer into a "paper fabrication" station. The cost of a power laser diode is a few tens to several hundred $, depending on quantity and power, and the price per W of laser diode power is expected to decrease steadily.

A paper fabrication station may generate revenue by turning paper into objects, with values associated to objects being much larger than the value of paper alone, and with low distribution costs, since a given paper stock can lead to many different paper objects. Personal fabrication kiosks may therefore be attractive prospects for business investment.

Advertising may be a source of revenue in personalized-packaging kiosks. Personalized objects to be finally assembled create proximity between the media and the user, and this feature may be appreciated for advertising purposes.

Desktop systems may generate revenue from ink supplies, including high-value absorbing ink cartridge. The system works readily on conventional paper; however, for thicker media further development would be necessary to achieve the appropriate absorption of the NIR absorbing ink and the required cutting efficiencies. As a consequence, proprietary media may be relevant and generate an ongoing revenue stream.

Conclusion

Laser diodes are available that allow laser cutting and scoring of paper and other thin media. This offers a unique opportunity to turn paper into 3-dimensional objects. This allows personalized fabrication at attractive costs, electronic distribution of objects, and new perspectives in terms of point of sale package creation and package advertising. This innovation can serve several business models. The technology is covered by a patent, and possible licenses with market-exclusivity may further enhance opportunities for selected companies to play a leading role in the transition from Digital Printing to Digital Fabrication.

References

[1] "The myth of the paperless office", A. Sellen and R. Harper, MIT Press.

[2] O. Acher, « peripherals which can be used to print and cut sheets of paper using a low power laser source », US Patent application 2005/0158107.

[3] H. Pagès, H. Piombini, F. Enguehard and O. Acher, "Demonstration of paper cutting using single emitter laser diode and infrared-absorbing ink", Optics Express (2005) http://www.opticsexpress.org/abstract.cfm?URI=OPEX-13-7-2351

[4] O. Acher, « New powers to your customers: low cost laser cutting in inkjet printers », Invited presentation at the 13th European Ink Jet Printing Conference, IMI Europe, Lisbon (2005).

Author Biography

Olivier ACHER is Chief Scientist at CEA. He graduated from the Ecole Polytechnique (1986) and obtained his PhD on optoelectronic materials and devices. He created in CEA a microwave and magnetic materials laboratory directed toward various applications. He is the author of 70 refereed papers, 20 patents, 3 licensing actions. He was awarded the IBM Young Scientist Award in 1990, the "Grand Prix Général Ferrié" in 2002, and nominated for the Leibinger Laser Innovation Prize in 2006.